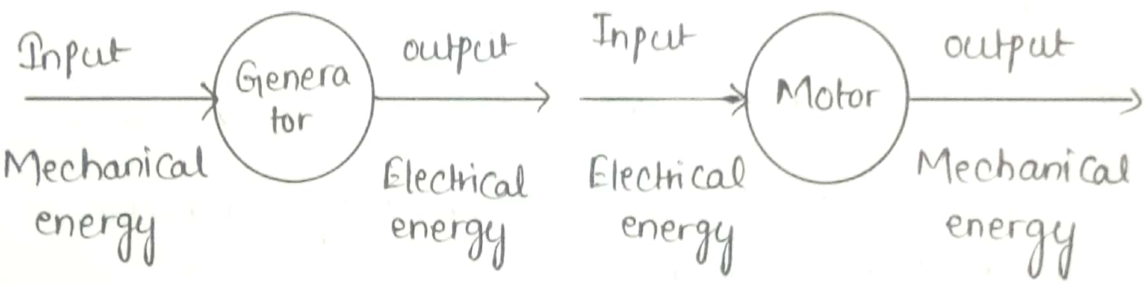
UNIT-2

DC GENERATORS

Electro Mechanical Energy Conversions :-

A Machine is required to Convert energy from one form to another form. A dc machine which Converts mechanical energy into electrical energy is called a dc generator. when electrical energy is Converted into Mechanical energy it is Called a dc motor. The energy Conversion is based on the production of dynamically induced emf. All these Conversions take place through Magnetic Medium.



Essential Requirements for Induced emf :-

(1). Conductors
(2). Magnetic flux / field
(3). Relative Motion between the Conductor and Magnetic field.

Faraday's I^{st} law :-

Whenever a Conductor cuts the magnetic field emf is Produced in the Conductor. This induced emf Causes a Current to flow if the Conductor Circuit is closed.

$$e = \frac{Q}{t}$$

Faraday's 2^{nd} law :-

The induced emf 'e' in the Conductor is directly proportional to the rate of change of flux linkages.

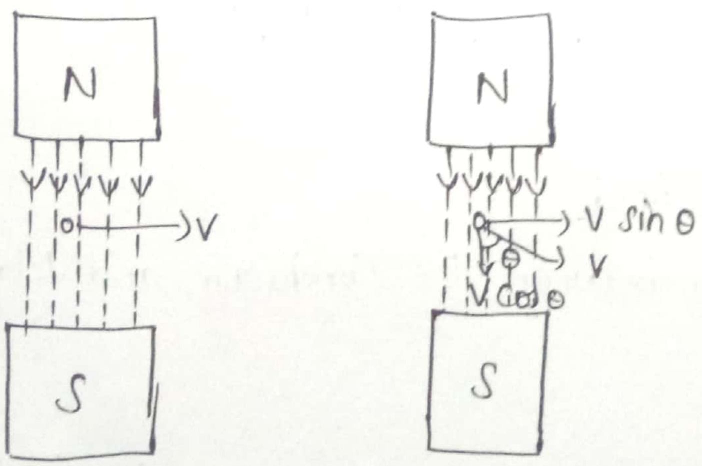
$$e = N \frac{d\phi}{dt}$$

Dynamically induced emf :-

Consider a single Conductor of length 'l' mts moving at right angles to a uniform magnetic field of flux density "B" wb/m^2 with a Velocity V m/sec. Suppose the Conductor moves through a small distance dx in dt seconds then the area occupied by the Conductor is = $l * dx$.

∴ Flux Cut by Conductor $d\phi$ = flux density * area occupied by Conductor.

$$d\phi = B * l * dx.$$



$e = Blv$
fig (a)

$e = Blv \sin\theta$
fig (b)

According to Faraday's law of electromagnetic induction emf "e" induced in the Conductor is given by

$$e = N \frac{d\phi}{dt}$$

$$= B l \frac{dx}{dt} \quad [N=1]$$

$$e = B l v \quad \left[\frac{dx}{dt} = v\right]$$

If the Conductor moves at an angle θ to the magnetic field [See fig (b)] then the Velocity at which the Conductor moves across the field is $v \sin\theta$.

The Component $V \cos\theta$ is parallel to magnetic field and hence no emf is induced in the Conductor due to this Component.

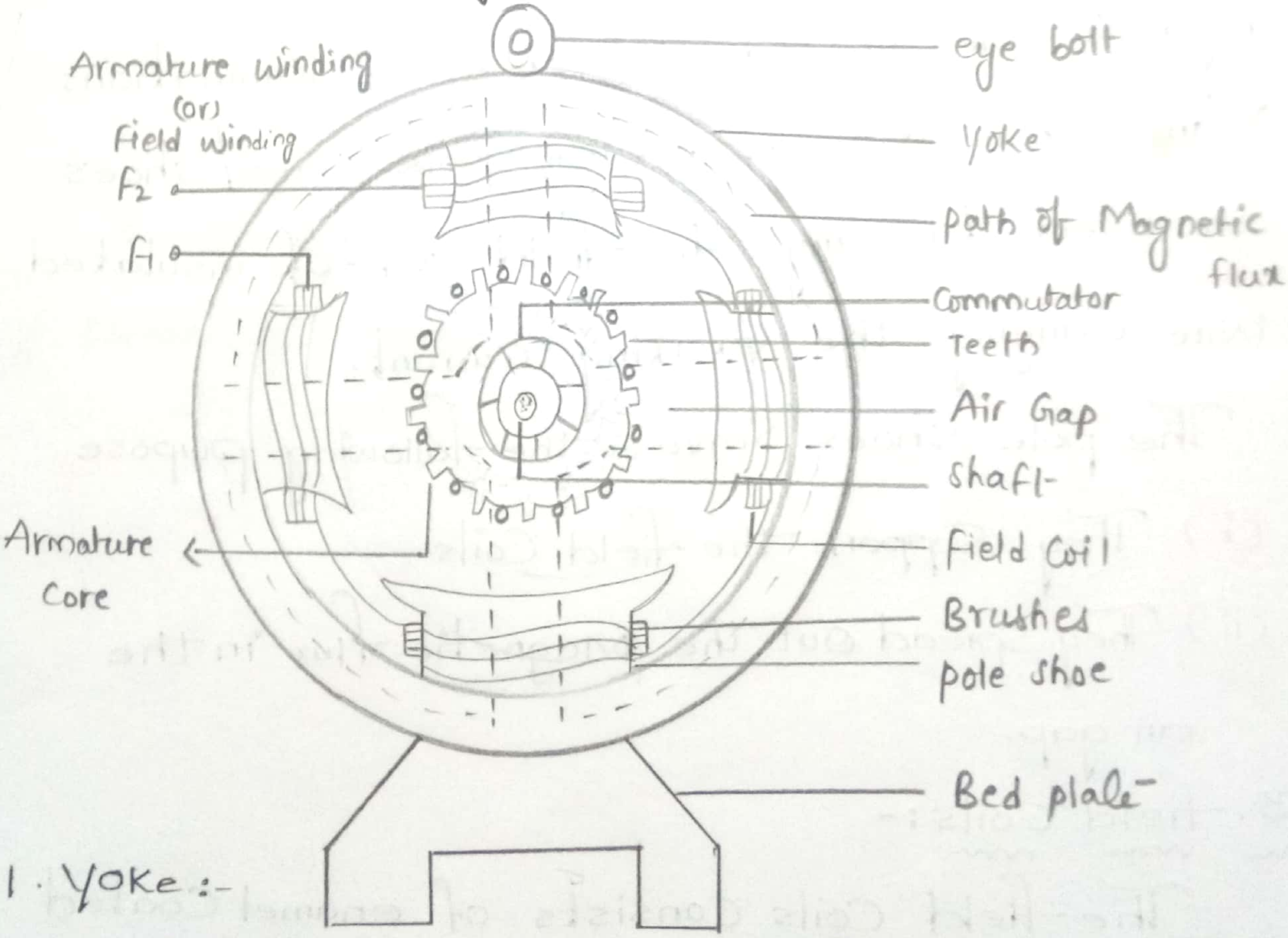
$$e = B l v \sin\theta$$

The direction of the induced emf Can be determined by Flemming's right hand rule.

Construction and parts of Dc generator :-

A practical Dc Generator Consists of the following essential parts.

1. yoke
2. pole shoes
3. field Coils
4. armature Core
5. Armature Winding
6. Commutator
7. Brushes
8. Bearings
9. shaf
10. bed plate



1. Yoke :-

The Outermost cylindrical frame is called yoke (or) body of Magnetic frame. It is Made up of Cast iron for Small Machines and for large machines

Usually Cast steel or rolled steel is employed. It is acting as a protective Cover for a whole Machine and also provides Mechanical Support for the Magnetic poles.

2. pole shoes:-

In Modern design, the Complete pole Cores and pole shoes are built of their laminations of annealed steel Which are rivitted together Under hydralic pressure. the thickness of laminations Varies from 0.25mm to 1mm pole Cores/shoes are used to Carry the field coils of insulated Wire Carrying the exciting Current.

The pole shoes Serves the following purpose

(i) They Support the field Coils

(ii) They spread out the Magnetic flux in the air gap.

3. field Coils:-

The field Coils Consists of enamel Coated Copper (or) Aluminium Wire. When direct Current is passed through the field winding it electromagnetise

The pole Core Which produces the required Magnetic flux.

4. Armature Core :-

Armature Core is cylindrical in shape and is Made up of high permeability silicon steel stampings or the laminations. The thickness of each lamination is about 0.3 mm to 0.5 mm. Each lamination is insulated from the other by then paper or Vanish. Since armature is a rotating part of the machine, reversal of flux takes place in the Core. Hence hysterisis losses are produced. To Minimise the Losses high permeability silicon steel is used.

5. Armature Winding :-

The armature Winding are Usually former Wound These are first Wound in the form of rectangular Coils. and then pulled into their proper shape in a Coil puller the Conductors of the Coils are insulated from each other by Varnish and placed in the armature slots which are lined with tough insulating material.

Open coil winding:-

Open coil winding is that winding which does not close on itself this type of winding is usually employed in a.c Machines but not in DC Machines.

Closed Coil winding:-

Which closes itself D.C Machines employ only Closed windings.

6. Commutator:-

It is the most important part of DC Machine the Commutator is of cylindrical shape and is made of Wedged shaped Segments of high Conductivity hard drawn Copper.

It Converts the alternating Current (AC) induced in the armature Conductor into Unidirection Current (DC) in the external Load Circuit in the generator action.

7. Brushes:-

Brushes are usually made of high grade Carbon because Carbon is Conducting Materials at the Same time in powdered form provides

Lubricating effect on the Commutator Surface.

8. Bearings:-

The function of the bearings is to reduce friction between the rotating and stationary parts of the machine mostly high Carbon steel is used for the Construction of bearing as it is Very hard material the types are

1. Bush bearings 2. Ball bearings 3. Roller bearings

9. Shaft:-

The shaft is a made of mild steel with a maximum breaking strength. the shaft is Used to transfer Mechanical power from or to the Machine. The rotating parts of armature Core, Commutator, Cooling fan are Keyed to the shaft.

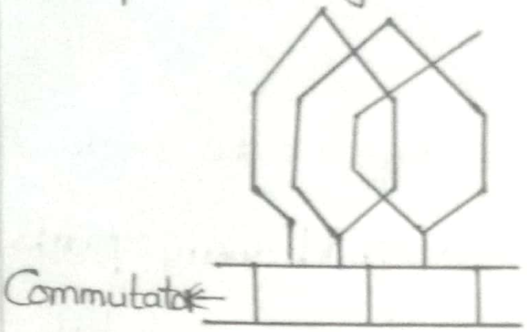
10. Bed plate:-

It is placed Under the entire Machine and it will give Support to the Machine.

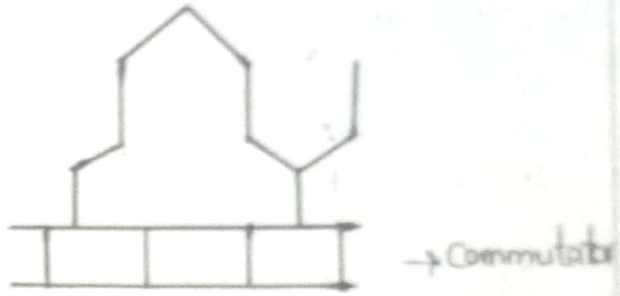
Armature Winding:-

It is defined as distance between the begining of two Consecutive terms.

Lap winding



Wave winding



Applications of DC Generators:-

1. Shunt Generators

(a). Lighting purposes (b) used to charge battery

(c). providing excitation to the alternators

2. Series Generators

(a) used in DC locomotives for regenerative braking for providing field excitation

(b) used as a booster in distribution networks

3. Compound Generators

(a) used in lighting and heavy power supply

(b) used in arc welding

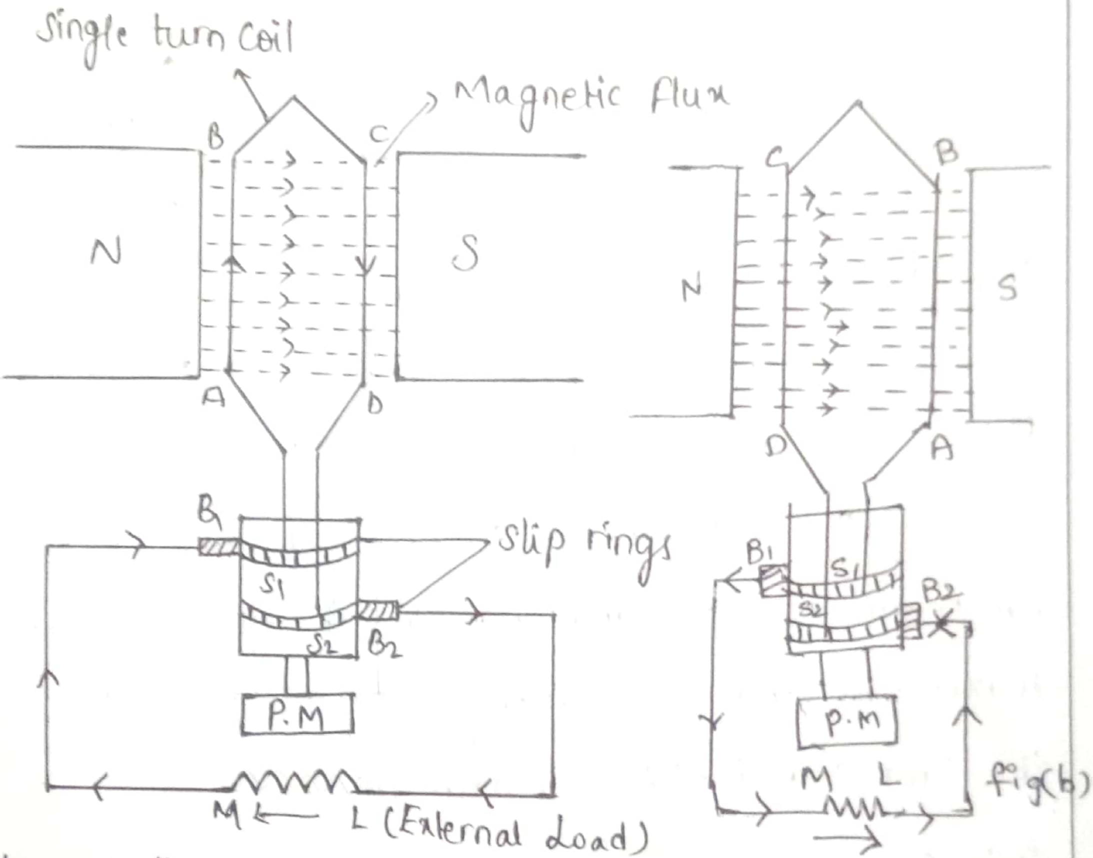
ELECTRICAL TECHNOLOGY

UNIT - I : DC GENERATORS

Generator :-

Generator is a machine which Converts Mechanical energy into electrical energy.

Working principle (or) operation of DC generator :-



fig(a) fig(b)

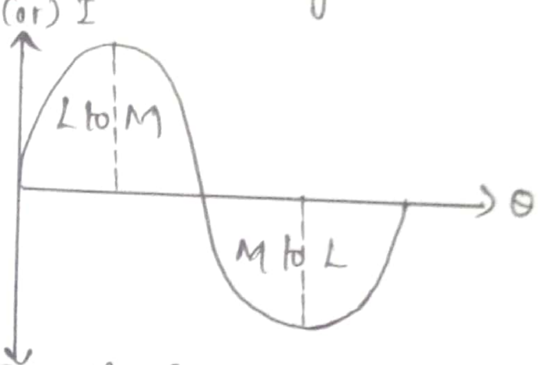
* . DC generator works on a principle of faraday's law of electro magnetic induction i.e, whenever Conductor cuts the Magnetic field, It produces E.M.F.
* . Let us Consider a single turn Coil (A, B, C, D) is placed in the Magnetic field as shown in figure.
* . The Conductor ends are Connected to two slip rings which are (not) mounted on shaft as shown in figure.

*. Two stationary brushes (B_1 and B_2) are mounted on slip rings which collects the current from slip rings and passes it to the external circuit.

*. Let take first position of the coil as shown in figure.

If $\theta = 0°$.

In this position, the induced emf is '0'. because the coil sides AB and CD are not cutting flux. These are moving parallel to flux lines.



If $\theta = 0°$ to $90°$:-

The coil sides AB and CD are moving with same angles to the magnetic flux and therefore the coil cuts the magnetic flux and then E.M.F will be induced.

At $\theta = 90°$ the coils sides AB and CD are perpendicular to magnetic flux and therefore the rate of flux cutting is maximum and flux linking is minimum. At this constant the Induced E.M.F is maximum.

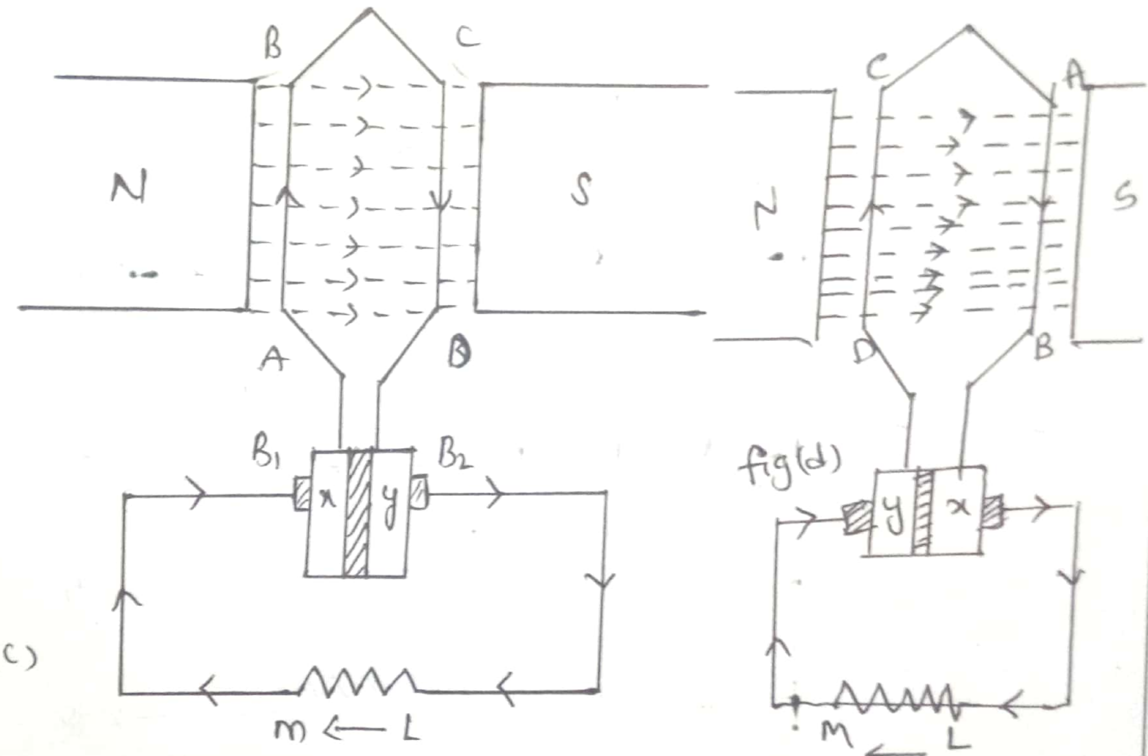
If $\theta = 90°$ to $180°$:-

In this position flux linking is gradually increases and rate of flux cutting is gradually decreases. In this position the Induced E.M.F is gradually decreased to zero and the current directions are ABCD S_2 B_2 LM B_1 S_1 A. shown in fig(a)

If $\theta = 180°$ to $360°$.

In this position the magnitudes of E.M.F are similar to those in first half cycle. The current through the load resistance reverses its direction for every half cycle. Such a current is called alternating current. To obtain direct current slip rings are replaced by split rings (or) commutator. Current directions are $DCBAS_1B_1\overrightarrow{ML}B_2S_2D$. shown in fig(b)

Action of Commutator :-



fig(c)

fig(d)

*. Commutator (or) split rings are made up of conducting materials and splitted into two segments which are separated by insulating material mica. The coil of two ends are connected in the segments as shown in figure.

*. It is observed that in that 1st half revolution, the current flow is $A-B-C-D-y-B_2-\overrightarrow{L-m}$ shown in fig (c)

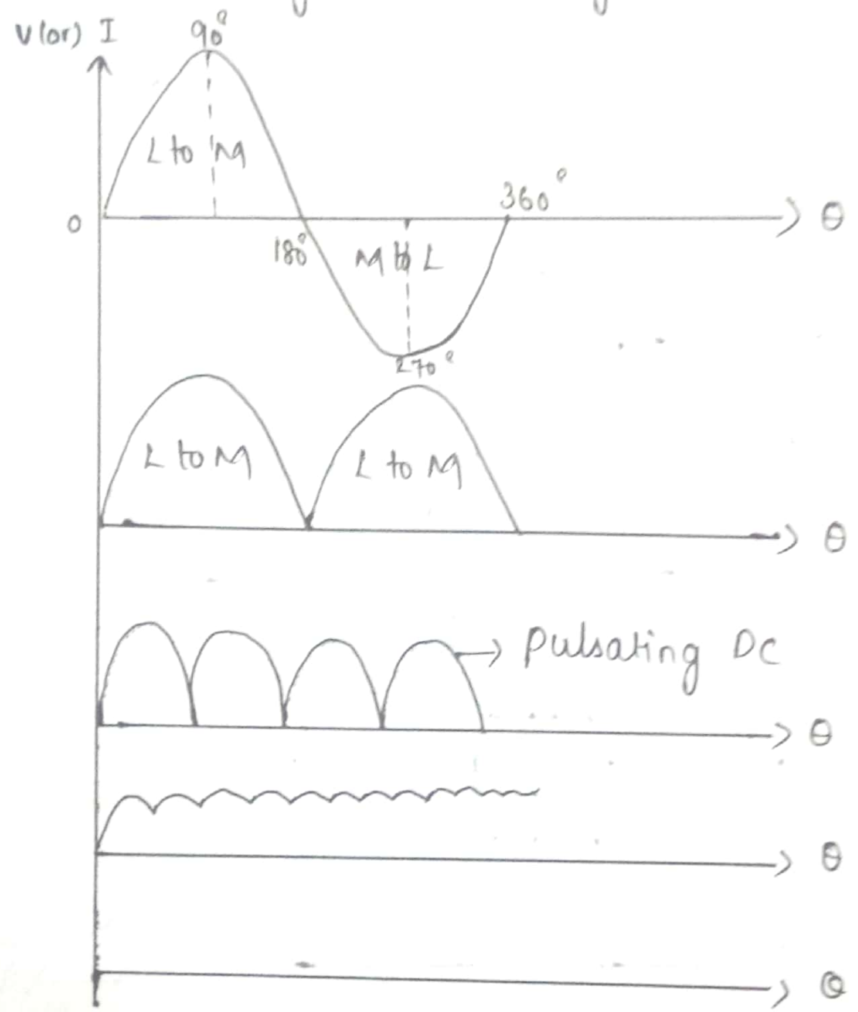
*. In the next half revolution the current flows along

$D-C-B-A-x-B_2-\overrightarrow{L-m}$ Shown in fig(d)

*. It is observed that the direction of current in the external

load current remains same (or) Constant.

*. By employing no. of Conductors no. of Commutator Segments the induced emf may be practically Constant i.e, DC.



Flemming's right hand rule :-

Direction of induced Current Can be determined by using flemming's right hand rule i.e, Stretch out the thumb, fore finger and middle finger of right hand perpendicular to each other. Fore finger indicates direction of magnetic field (or) flux, thumb indicates motion of the Conductor and middle finger indicates direction of induced Current.

*. MOTOR:-

A DC Motor works on the principle of "whenever current carrying conductor placed in magnetic field (or) flux, it experiences a mechanical force and tries to rotate".

The experienced mechanical force $F = Bil$

Where 'B' is flux density in weber/m² (wb/m^2)

'i' is supply current in Amperes (A)

'l' is length of conductors in meter (m).

→ Essential requirements for DC Motors:-

- Magnetic flux
- Conductors (or) armature
- Electrical Supply

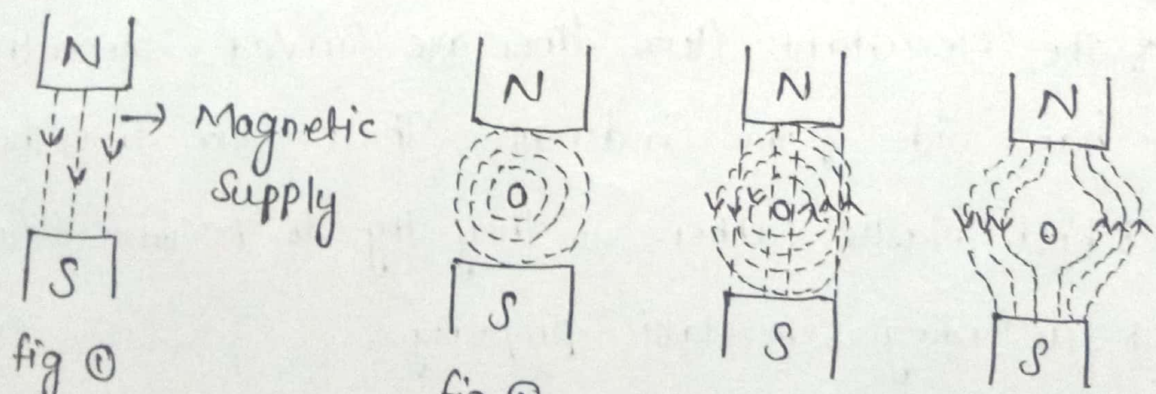


fig ① fig ② fig ③ fig ④

→ Field winding is around the pole core and the ac supply is given to it, it produces magnetic flux of uniform flux density "B" as shown in fig ①

→ A Conductor of length 'l' meters is placed perpendicular to the main magnetic field (or) flux and a dc supply given to it, it carriers a current of 'i' amperes and flux produced by the conductor is in the form of concentric circles around the conductor as shown in fig ②.

→ The resultant flux obtained by the interaction between main magnetic flux and armature flux as shown in fig ③.

→ The main magnetic flux & armature flux, both are in same downward direction of left hand side of the conductor. So, these flux lines are added to strengthen the magnetic flux on left hand side of the conductor.

→ On the right hand side of the conductor, the main magnetic flux is downward and armature flux is upward & hence the resultant flux decrease (or) weakens on right hand side of the conductor.

→ Most of the resultant flux lines are curved & concentrated on left hand side of the conductors. These flux lines behaves like stretched elastic rubber. So they try to become straight and short according to elastic property.

By this, it experiences a mechanical force & conductors tries to rotate from left to right as shown in figure ④.

→ The direction of experienced force can be determined by the "fleming's left hand rule"

*. Fleming's Left Hand Rule :-

Stretch out thumb, force finger & middle finger of left hand ⊥r to each other. The force finger indicates the direction of force & thumb indicates the direction of motion of conductor and middle finger indicates current direction.

Applications of DC motor

1). Shunt motor – used where ~~high starting torque~~ constant speed needed

a). Lathe machines (b) Fans (c) Blowers.

(d) conveyors (e) spinning machines

2). Series motor – used where high starting torque required

(a) Traction system (b) Cranes (c) air Compressors

(d) Vaccum cleaner

3). Compound motor – used where high starting torque & constant speed

(a) Conveyors (b) Elevators (c) Rolling mills.

* UNIT-4 *

Transformers

Introduction

- Alternating voltages can be raised or lowered as per the requirements in the different stages of electrical network as generation, transmission, distribution and utilization. This is possible with a static device called transformer.
- We can define transformer as below:

The transformer is a static device (piece) of apparatus by means of which an electrical power is transformed from one alternating current circuit to another with the desired change in voltage and current, without any change in the frequency.

- Thus the transformer is used to increase or decrease the voltage as per the requirement.
- The use of transformers in a.c transmission system is shown in the Fig. 3.1.1,

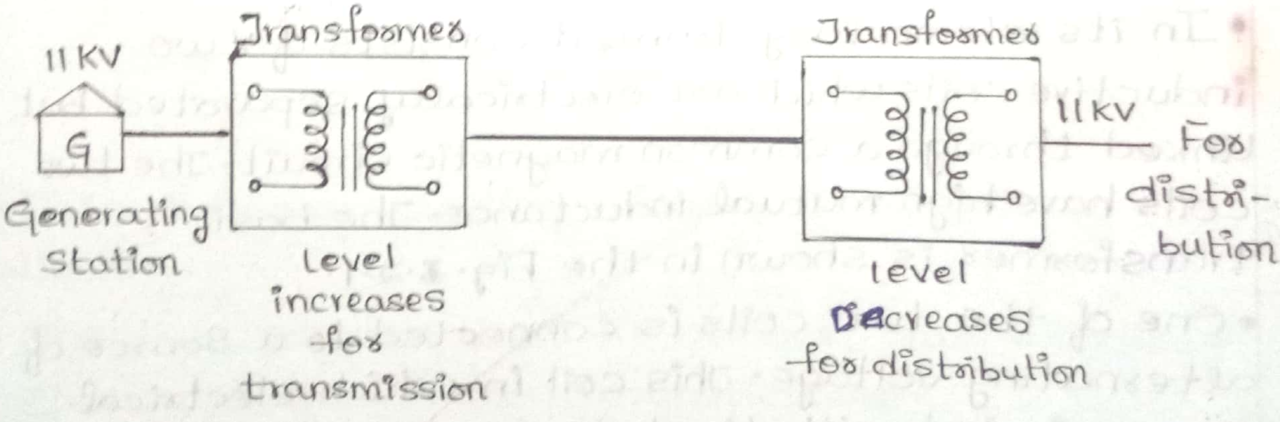


Fig. 3.1.1 Use of transformers in transmission system

Imp Working Principle

- The transformer works on the principle of mutual induction which states that when two coils are inductively coupled and if current in one coil is changed uniformly then an e.m.f gets induced in the other coil.

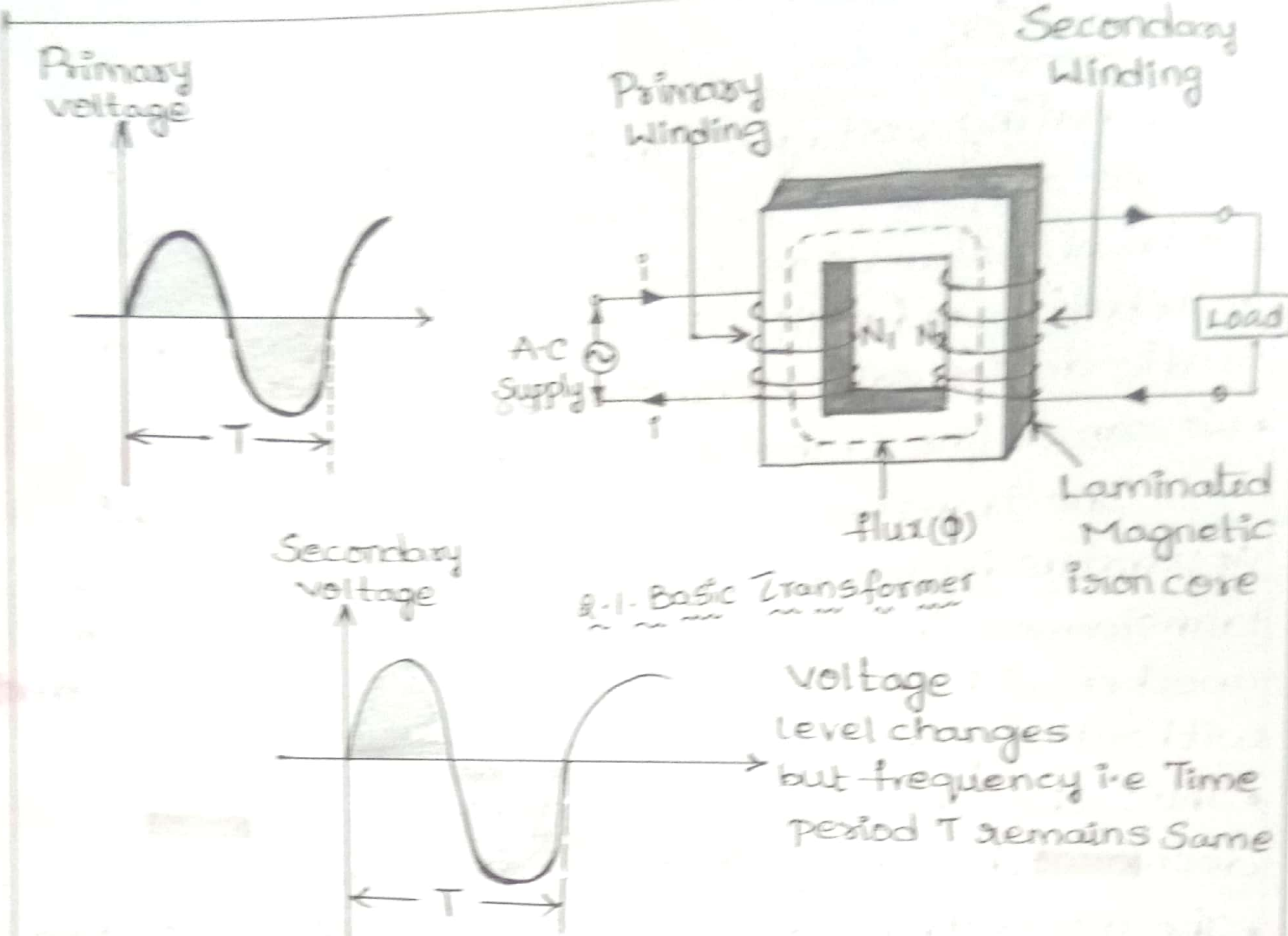


Fig. 3.2.1 Basic transformer

- In its elementary form, it consists of two inductive coils which are electrically separated but linked through a common magnetic circuit. The two coils have high mutual inductance. The basic transformer is shown in the Fig. 3.2.1.
- One of the two coils is connected to a source of alternating voltage. This coil in which electrical energy is fed with the help of source is called primary winding (P).
- The other winding is connected to load. The electrical energy transformed to this winding is connected to the load. This winding is called secondary winding (S).
- The primary winding has N_1 number of turns while the secondary winding has N_2 number of turns.

- When primary winding is excited by an alternating voltage, it circulates an alternating current. This current produces an alternating flux(ϕ) which completes its path through common magnetic core as shown dotted in the Fig. 3.2.1. Thus an alternating flux links with the secondary winding.
- As the flux is alternating, according to Faraday's law of an electromagnetic induction, mutually induced e.m.f. gets developed in the secondary winding.
- Symbolically the transformer is indicated as shown in the Fig. 3.2.2.

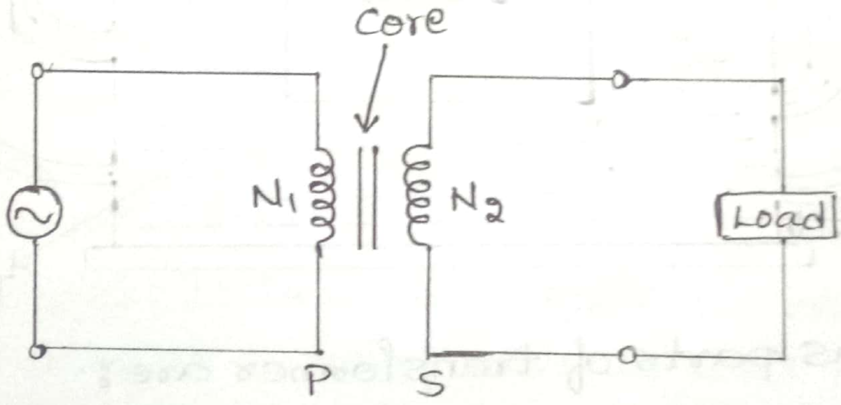
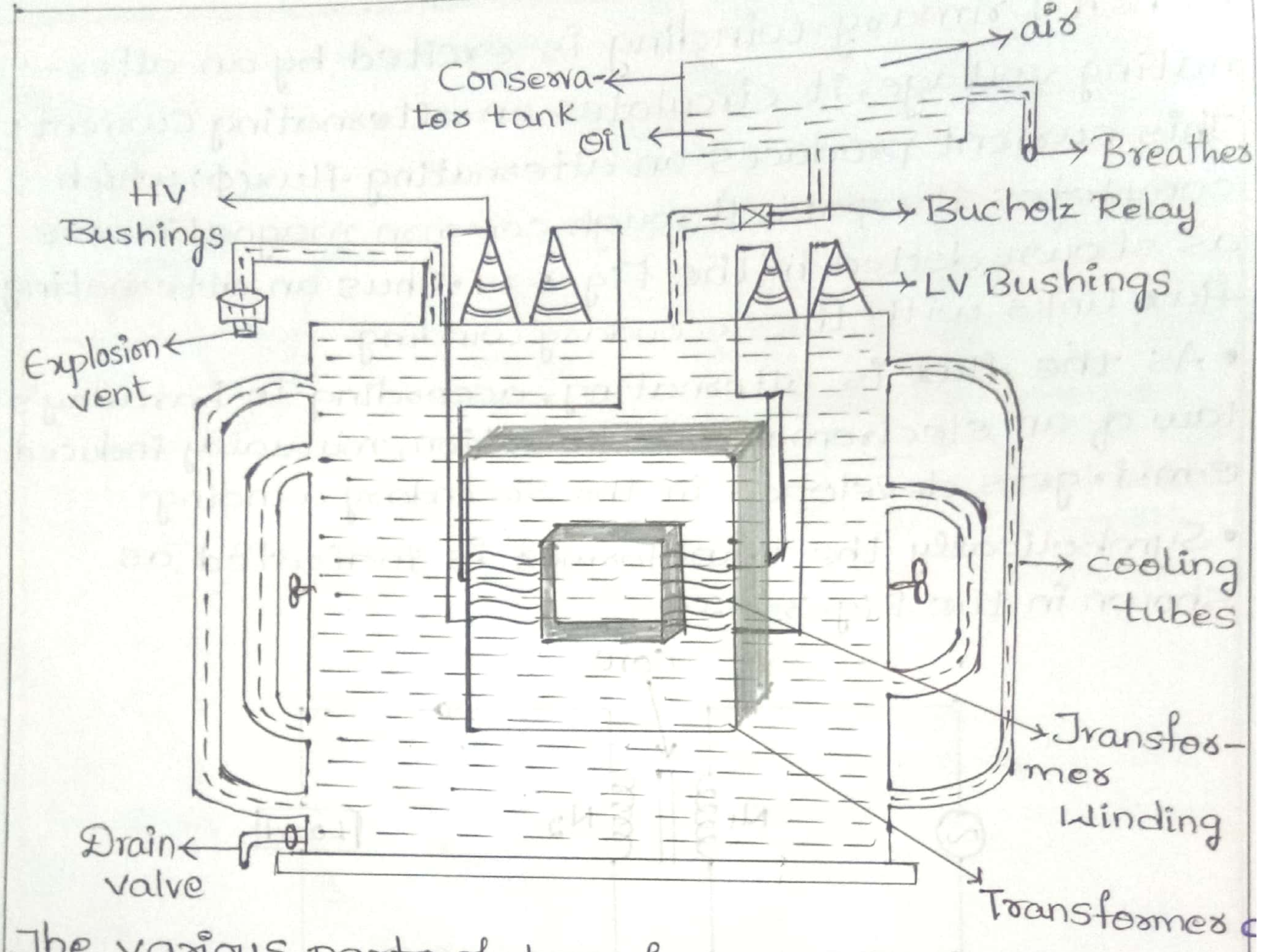


Fig. 3.2.2 Symbolic representation

- P is primary winding while S is secondary winding.
- The two parallel lines in between two windings represents the common magnetic core.
- Thus though there is no electrical contact between the two windings, an electrical energy gets transferred from primary to the secondary.

Parts of transformer :- Construction of Transformer



The various parts of transformer are:

1. <u>Core</u>: It is made up of high grade silicon steel laminations as its function is to carry the flux produced by the winding.

2. <u>Limb</u>: It is vertical portion of the core and its function is to carry the windings.

3. <u>Yoke</u>: The top and bottom horizontal portion of the core is called yoke. Its function is to carry the flux produced by one winding to reach to the other winding and provided the low reluctance path to the flux.

4. <u>Windings</u>: The coils used are wound on the limbs and are insulated from each other. The function of the windings is to carry the current and produce the flux necessary for the functioning of the transformer.

5. Conservator: The oil in the transformer expands when temperature inside the transformer increases due to heat while it contracts when the temperature decreases. The function of the conservator is to take up the expansion and contraction of the oil without allowing it to come in contact with the ambient air.

6. Breather: Smaller transformers are not fully filled with oil and some space remains between oil level and tank. The tank is connected to atmosphere by vent pipe. When oil expands air goes out while when oil contracts the air is taken in. The breather is a device which extracts the moisture from the air when the air is taken in and does not allow oil to come in contact with the moisture. The breathers contain the silica gel crystals which immediately absorb the atmospheric moisture.

7. Explosion Vent: It is a bent pipe fitted on the main tank which acts as a relief valve. It uses nonmetallic diaphragm which bursts when pressure inside the transformer becomes excessive which releases the pressure and protects the transformer.

8. Buchholz relay: It is a safety gas operated relay connected to transformer. When the fault gets developed inside the transformer, the gases are released. The Buchholz relay is operated with these gases and trips the circuit breaker to protect the device.

Types of single phase transformers:

- The various types based on the construction of single phase transformers are,

1. Core type and

* Three phase Induction Motor *

Construction of 3-ϕ Induction Motor:

Three phase Induction motor is the most popular type of AC motor. It is very commonly used for industrial drives. Since it is cheap, robust, efficient and reliable.

A Three phase Induction motor essentially consists of two parts

(i) Stator

(ii) Rotor

→ 1) Stator:

Stator is the stationary part of the machine which is made up of high grade alloy steel laminations to reduce eddy-current losses. The laminations are slotted on the inner-periphery and are insulated from each other. These laminations are supported in stator frame of cast in (or) steel plate. The insulated stator conductors are place in these slots. The stator conductors are connected to form a three phase winding. it may be either stator (or) Delta connected.

The stator is connected to a 3-phase AC Source it establishes a rotating field. which rotates at the Synchronous Speed.

i.e., $$N_S = \frac{120f}{P}$$

→ 2) Rotor:

Rotor is rotating part of the machine. Rotor is also made up of thin laminations of Same material as stator. The laminated cylindrical core is mounted on the shaft. These laminations are slotted on their outer periphery to place rotor conductors.

There are two types of induction motor rotors

(i) Squirrel-cage rotor (or) Simply cage rotor
(ii) phase wound (or) Wound rotor (or) Slip ring rotor

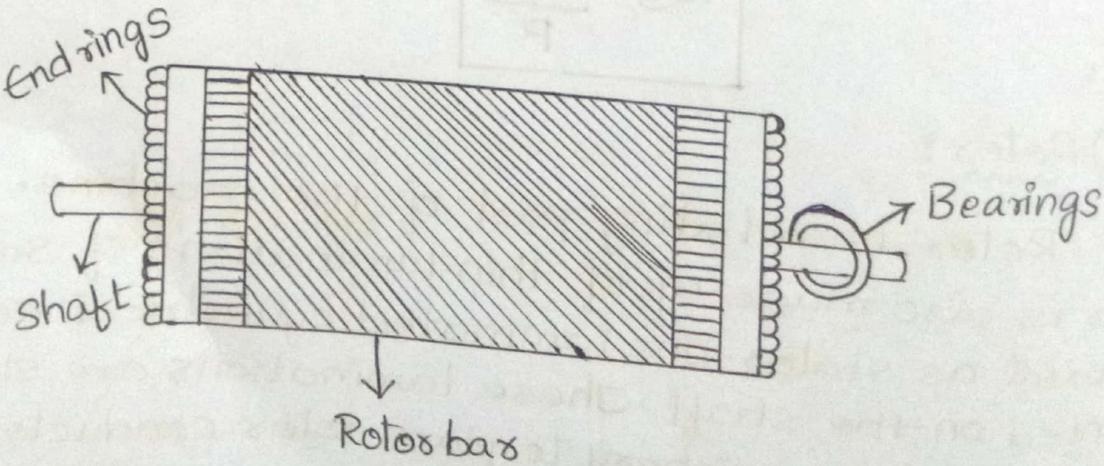
(i) Squirrel-cage rotor:

Most of the induction motors are of Squirrel-cage type. squirrel-cage type rotor has very Simple in construction. This type of rotor consists of a cylindrical laminated core, having parallel slots on it. Rotor conductors are placed in these slots. In this, type of rotor, heavy bars of copper, aluminium or alloys are used as rotor conductors.

Rotor slots are slightly skewed to achieve the following advantages.

(1) Uniform torque is produced and noise is reduced during operation.
(2) It reduces locking tendency of the rotor.
(3) Increases the effective transformation ratio between stator and rotor

At each end of the rotor, the conductors are short circuited by heavy end rings of the same material. Then this rotor construction looks like a Squirrel-cage rotor bars are permanently short circuited, Hence it is not possible to add any external resistance to armature circuit.



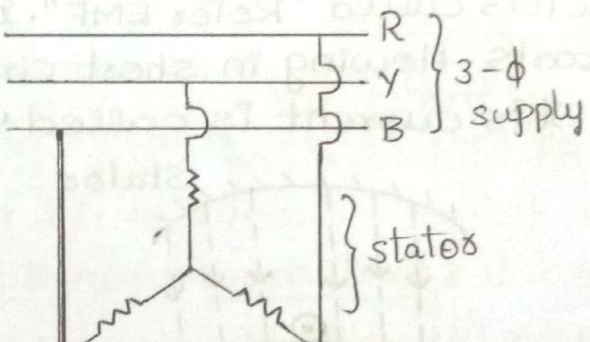
(iii) phase wound (or) slip ring motor:

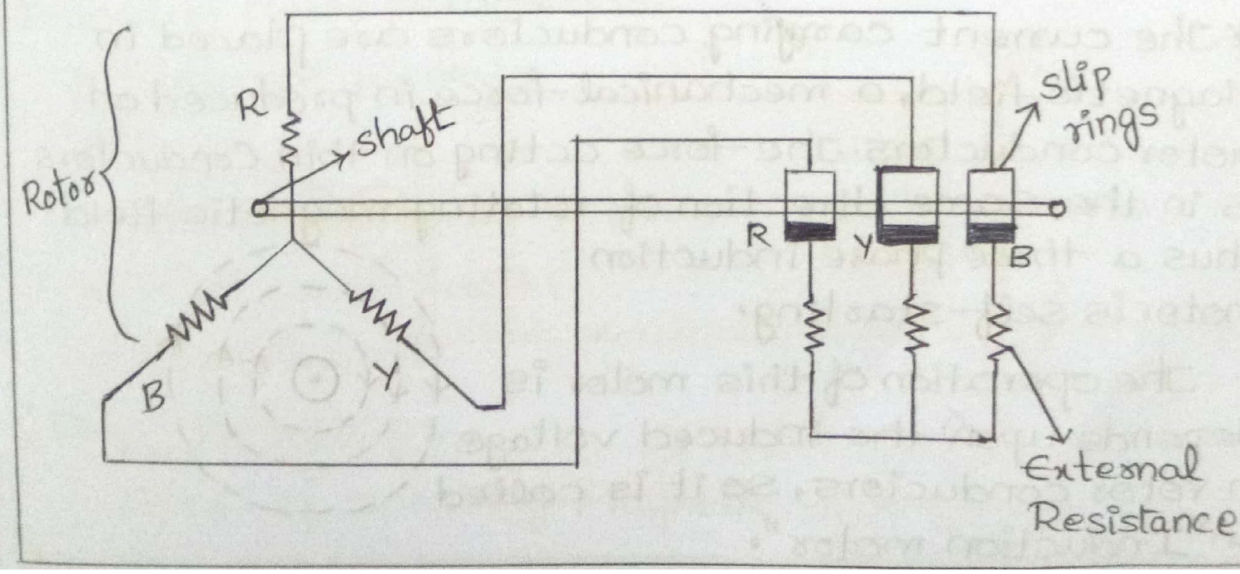
The wound rotor consists of slotted armature. The insulated conductors are placed in the slots and connected to form a three phase double layer distributed winding similar to the stator winding. The rotor windings are connected in star.

The open ends of the star circuit are brought outside the rotor and connected to three insulated sliprings. The sliprings are mounted on shaft with brushes resting on them. The brushes are connected to three variable resistor connected in star. The purpose of sliprings and brushes in provide external resistance in the rotor circuit.

(1) To increase the starting torque and decrease the starting current.

2) To control the speed of the motor





Working principle of 3-ϕ Induction Motor:

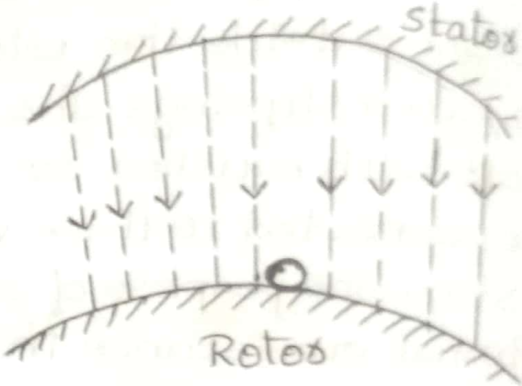
Induction motor works on the principle of electro magnetic induction

* When three phase supply in given to the three phase stator winding, a rotating magnetic field of constant magnitude in produced, speed of this rotating magnetic field in Synchronous Speed.

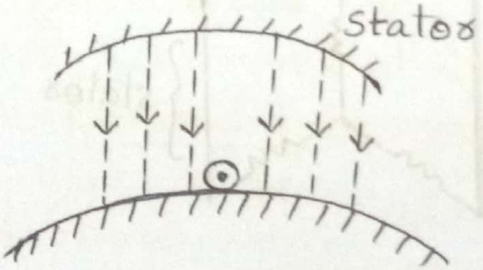
i.e., $$N_S = \frac{120f}{P}$$

where f = frequency in Hz

P = No. of poles

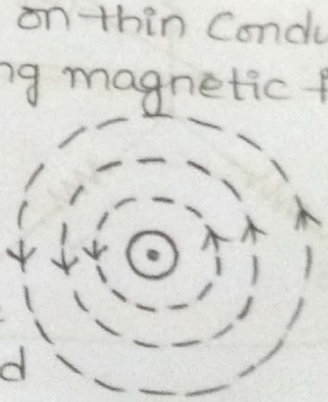


* The rotating field passes through the air gap and cuts rotor conductors. Whenever conductor cuts the flux emf gets induced. The EMF induced in the rotor conductors called "Rotor EMF". Due to this EMF, Currents starts flowing in short circuited rotor conductors. This current is called "Rotor current".



* The current carrying conductors are placed in Magnetic field, a mechanical force in produced on rotor conductors. The force acting on thin Conductors is in the same direction of rotating magnetic field. Thus a three phase induction motor is self-starting.

The operation of this motor is depends upon the induced voltage in rotor conductors, so it is called an "Induction motor".



Applications of 3-φ Induction motor

1. Lifts 2. Cranes 3. Large exhaust fans

4. Lathe machines 5. Crushers

6. Oil extracting mills.

7. Textiles.

Applications of Transformers:

1. It is used to increase & decrease the Alternating voltages in electric power applications.

2. It is used in voltage regulators, voltage stabilizers, power supplies, rectifiers, etc.

Construction of Alternator :-

The main parts of Sychronous generator are

(1). Stator (Armature)

(2). Rotor (Field Magnet System)

Stator :-

The Stator frame Consists of a Cast iron which Supports the armature Core having Slots on its inner periphery for housing the armature Conductors. Since the field Rotates in between the Stator, so that flux of the rotating field cuts the Core of the Stator Continuously and Cause eddy current loss in the stator Core. To minimise the eddy Current loss, the Stator Core is laminated. The stator formed of laminations of Special magnetic Iron or steel alloy (silicon steel) Ventilating ducts are provided in the Stator Core parallel to the axis of the frame to facilitate improved Cooling Conditions.

Rotor :-

From the Construction point of view there are two types of rotors.

(1). Salient pole type (projected pole type).

(2). Non Salient pole type (smooth Cylindrical or round rotar type).

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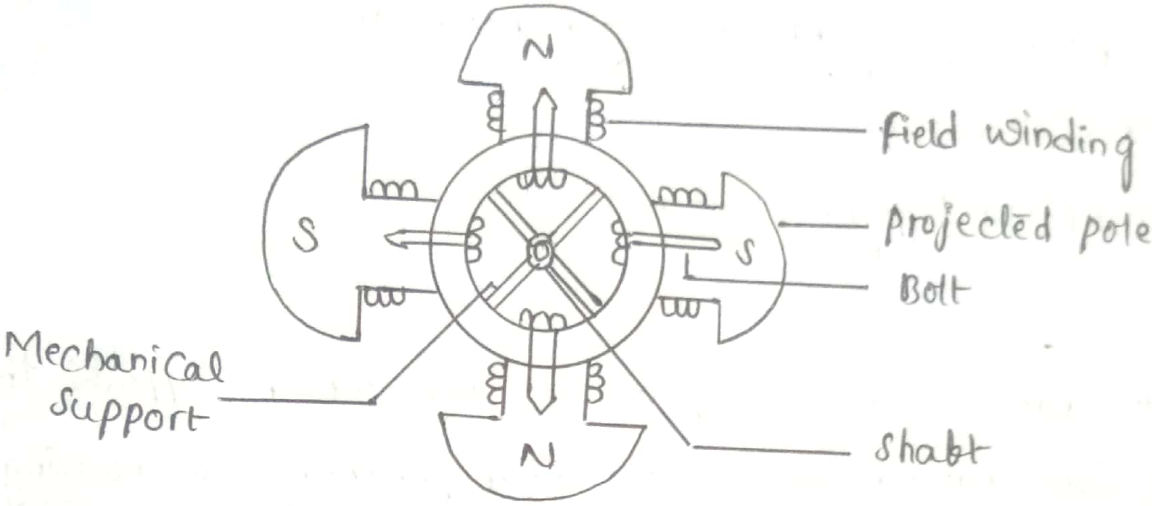
Salient pole type Rotor:-

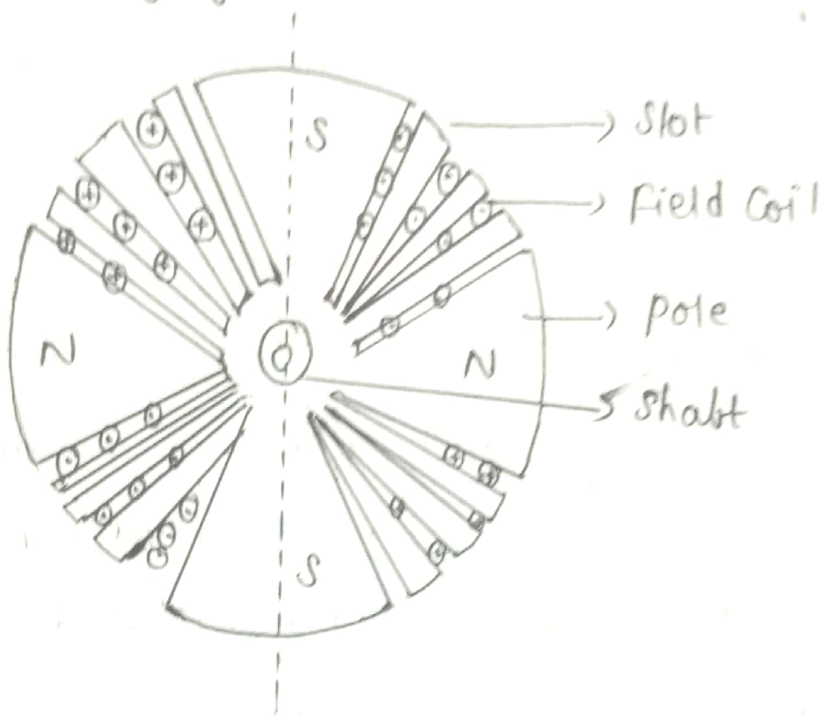


This type of rotor generally carries a large number of poles (p) which are prominently projected. It is generally used in low speed hydrogenerators. The poles carry the field winding incase of large machine copper strips are used for field winding. The cores of the poles are bolted to a heavy wheel made of cast steel. Although the size of the Rotor (diameter is large, its axial length is short). The poles are laminated to reduce the iron losses due to eddy currents. Horizontal shaft is preferred for machines driven by Internal Combustion engines. But Vertical shaft is preferred for high power low head plants.

Non Salient pole type Rotor (Cylindrical):-

In this type of rotor, poles do not project like in the salient pole type but the rotor has slots in which the field winding is housed. The central polar areas are surrounded by the field

Windings and the flux density is maximum in these areas. In modern turbo - generators the rotor is made of silicon steel forging.



This type of Rotors are generally used in high speed Turbo - alternators and are made of chromium, nickel, molybdium, steel. The diameter of rotar is generally made small but with very large rotar length inorder to reduce the centrifugal forces on the windings at high speeds. This type of rotor gives better balance and smooth operation and has low windage losses because of less air friction due to rotation.

Working of Alternator :-

An alternator or synchronous generator works on the principle of faraday law of electromagnetic induction. It states that whenever a Conductor moves in a magnetic field an emf induced in the Conductor. The direction of induced emf can be found by using fleming's right hand rule.

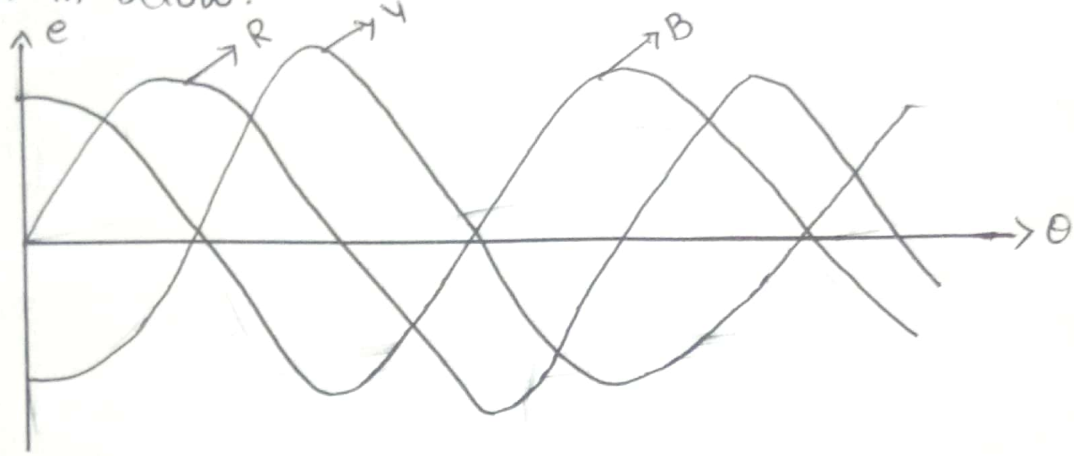
The Conductor is formed into a Coil of multiple turns Called armature winding. In the alternator, the armature is Stationary. Therefore it is placed inside the stator. The field windings are used for generating a magnetic field.

Since the field is moving, field windings are placed inside the rotor. The field windings are energized through slip rings to form an electromagnet having both north and South pole.

The rotor rotates with the help of prime mover. The magnetic field poles also rotate at the same speed as the ~~rotate~~ rotor. Thus the varying magnetic flux cuts the armature winding inducing current in the windings.

The induced emf depends on the alignment of the magnetic field and armature winding. It is maximum when the armature winding and magnetic field lines are perpendicular and it is zero when it is in the same alignment.

The Stator has Seperate armature windings for each Phase placed at exactly 120° displacement therefore. The induced emf is 120° a part as in 3-ϕ alternating Current as shown in below.



The frequency of induced emf depends on the Speed as well as no. of Poles.

$$f = \frac{NP}{120}$$

Applications :-

(1). Auto Mobiles.

(2). In locomotives.

(3). Power generating Plants.

(4). In marine and Navy boats.

(5). Radio frequency transmission.